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CIRCULAR No. 154
JULY, 1916

IRRIGATION PRACTICE IN GROWING SMALL FRUITS IN CALIFORNIA*

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The census returns show that in the period between 1899 and 1909 the acreage in small fruits in California was increased more than fifty per cent, and that the production and value of the fruits were nearly doubled. In 1909, strawberries led with 4,585 acres, or nearly one-half

Fig. 1.—Strawberry field in Pajaro Valley. This shows the location of plant beds, irrigation furrows, and distributing flumes.

of the whole area devoted to small fruits, followed by blackberries and dewberries with 2,576 acres, raspberries and loganberries with 1,992 acres, currants with 407, gooseberries with 74, and cranberries with 53 acres. The irrigation of these small fruits is a very important factor

* Based on work done under co-operative agreements between the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture, and the State Department of Engineering of California, and between the Office of Public Roads and Rural Engineering and the California Agricultural Experiment Station.

in their production, and the present circular has been prepared for the purpose of describing and analyzing the irrigation practices in the important berry centers of the state.

PREPARATION OF LAND FOR IRRIGATION

In most sections of California small fruits are grown under irrigation, so that it is necessary to take into account careful preparation of the land before planting. It is especially essential that strawberry fields be well graded, because the streams of water used are quite small, and because, unless the land has an even slope, the application of water will not be uniform, but water will collect in depressions and flood over the berry vines, sometimes killing them if continued for any length of time. Less care is usually employed in preparing land for bush berries, however, and the "finishing" process referred to below is often omitted. When a strawberry field is laid out according to one of the most widely-used furrow systems, described later, the ridges and irrigation furrows are made to be permanent during the life of the planting, but the furrows in a blackberry or raspberry field are usually plowed up and renewed every year, with the result that less care is taken in making them. Furthermore, there is less danger to the plants from minor irregularities in the irrigation of bush fruits, as these are set quite far apart and are deeper-rooted, making unnecessary a close approach of the water to the plants. With the shallower-rooted strawberries, on the other hand, it is desirable to carry the water as close to the tops of the ridges as possible without actually flowing over them. Nevertheless, a carefully established grade is highly desirable in bush-berry fields as well as for strawberries, for where the handling of water is once made easy, the saving in labor and cost of water may in some years represent the difference between profit and loss.

SURVEYING

A survey of the field is the first step in its preparation for irrigation, and a contour map is of much assistance. The following method of laying out strawberry fields is used satisfactorily in parts of Pajaro Valley on gently rolling land: The high edge of the field is first chosen for the location of the main irrigation flume. Then after determining from the contour map the various positions of furrows and lateral flumes, which are such as to require the least grading, each lateral flume line is marked out on the ground and stakes are driven every 30 or 40

feet along such line. Through the first stake a line of levels is run in the direction the furrows are to take, which is not necessarily at right angles to the lateral flume, and grade stakes are set every 30 feet, balancing the cuts and fills. This grade is usually 1 to 2 inches per 100 feet, or else the furrows are made level from end to end. Then an average line is run through the next stake parallel to the first line and grade stakes are set similarly, and the operation is repeated through each stake along each of the lateral flumes. Some growers set stakes every 50 feet apart, but this of course depends upon the character of the ground, more stakes being required when the surface is rough than when it is fairly level. The cost of surveying is from $2.00 to $2.50 per acre.

PLOWING AND CULTIVATING BEFORE PLANTING

Plowing and harrowing are not only indispensable in securing a good bed for planting, but are necessary in many cases to loosen the soil so that it may be easily moved by the leveling implements. The practice in some sections is to plow twice before grading, the first time to a depth of 8 to 12 inches and the next time shallower, and to harrow after each plowing, continuing the harrowing as occasion may require until grading has been completed. Other growers plow before and after leveling, and still others only afterwards, cultivating the ground several times thereafter. To avoid a dead furrow in the center of a small tract the practice sometimes is to run the plow once up and down the center line of the field, throwing the soil outwards, and then to reverse the plow and go up and down the furrow, throwing the soil into it, and so on around the field, the last work being done along the borders. Although this leaves a low area around the edges of the tract, it is less objectionable than a trench through the center. The total cost of the several plowings and cultivatings varies from $5 to $10 or more per acre, depending upon the number of operations.

GRADING

Methods of leveling land for small fruits and implements used are found to vary somewhat in different sections. The Parajo Valley method used in conjunction with the surveying practice described above is as follows: If the cuts and fills are very great a Fresno scraper is used first and the finishing is done with a "berry leveler," (fig. 2), and if not great the leveler is used alone. This implement has two wheels on an axle 7 feet or more long, to which is attached an adjust-

able wooden drag, shod with iron, and having aprons on the side. It is drawn by one or two horses, depending upon the size. Very close work can be done by the driver standing on the machine and operating the adjusting lever. With this leveler the ground is worked back and forth along the line of the grade stakes for 15 feet on each side, or half the distance to the next row of stakes; then it is taken to the next line and the ground on each side of that leveled independently of that on each side of the first line; and so on down. This method is followed because it is more essential that each furrow shall have its proper grade than that any set of furrows shall bear a particular relation to an adjoining set. However, in case of a deep swale the line of the

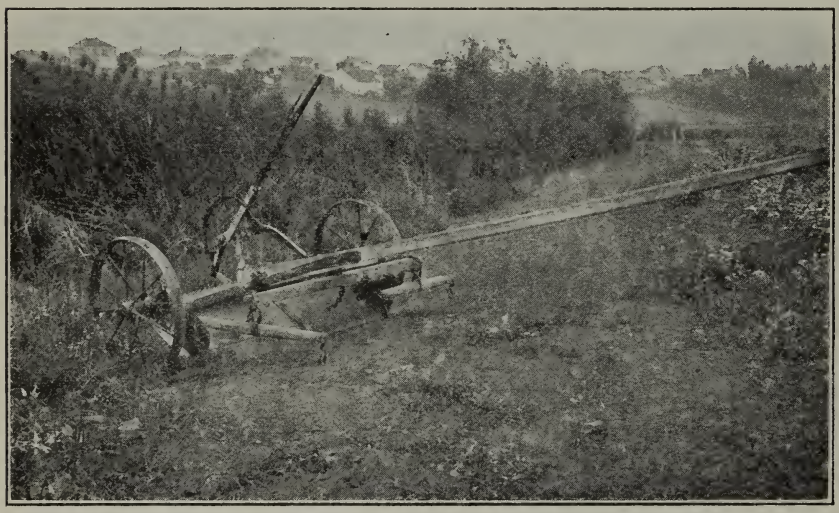

Fig. 2.—Leveler used in Pajaro Valley berry district. This is used for the final grading after the field has been leveled approximately with Fresno scrapers.

ditches may be changed to fit it. This method is peculiarly adapted to fairly rolling land where it is not desired to make long hauls with the scraper.

On the level valley floor lands of the state the usual practice is to level each small field as a whole and to run all furrows in the same direction.

In some sections, after leveling the field approximately to the grade stakes, the "finishing" is done with a drag or float. This consists of two 2-inch by 12-inch planks 12 to 16 feet long set parallel on edge and connected by three 2-inch by 12-inch cross-pieces 5 to 8 feet

long, one at each end of the structure thus formed, and the third in the center. Diagonal strips of wood are used as braces. The central cross-plank is set on edge and vertical, but the two outer pieces slant backwards from top to bottom. This implement is drawn by two or more horses.

A satisfactory and inexpensive home-made leveler for berry fields in use in the Gardena-Moneta section of Los Angeles County is shown in figure 3. The rear wheels are mower-wheels, set on an axle 5 to 6 feet long, and the single front wheel is of any convenient material and size. The side boards are 2-inch by 12-inch planks 8 to 11 feet or more in length. The scraping device, which is controlled by a lever, is 4 to

Fig. 3.—Leveler used in Gardena-Moneta berry district. A simple and cheaply made implement, used for final grading.

5 feet in width, made of 2-inch by 6-inch pine fitted over curved cleats and shod with iron on the bottom edge. The side shields or aprons are of galvanized iron. The smaller implement is drawn by two horses and the larger by four, the driver standing on the floor back of the adjusting lever.

Where large heads of water are available the precaution is sometimes taken to flood the field after leveling and then to fill the settled spots.

If the berry field is to be laid out on a steep hillside, which is often done in Pajaro Valley and elsewhere, no grading is done, but the irrigation furrows are made to follow the contours of the hill (fig. 4). The practice in the Sierra Nevada foothills of Placer County is to run

the furrows directly down the slope instead of along the contours, thus following the system used extensively there in orchards. This is feasible where very small streams of water are run for long periods of time. With such irrigation practice, no preparation of the land is attempted other than to provide a proper bed for planting and to make the small furrows.

No figures can be given on the cost of leveling land that will apply to all conditions, because the cost depends entirely upon the character of land to be graded. Such cost may range from $3 to $4 up to $40 or more per acre, but the maximum is seldom expended in the case of small fruits unless the land is to be kept permanently in some irrigated crop.

Fig. 4.—Sidehill planting, Pajaro Valley. Where strawberry fields are laid out on hillsides in this section, the irrigation furrows are made to follow the contours of the land. In Placer County the furrows are smaller and run directly down the slope.

HEAD DITCHES AND FLUMES

After grading, the tract is ready for the installation of ditches and furrows. The main conduit and supply laterals may be earthen ditches, open flumes, or pipes, the most widely used being small wooden flumes. Earth ditches may be made at a small initial cost, $2 or $3 per acre, but the labor and consequent cost of applying water will be increased because of the operation of opening and damming up furrows at each irrigation. Another disadvantage lies in seepage losses. Wooden

flumes, on the contrary, require only a small amount of attendance, and leakage may be kept at a minimum. Concrete flumes or underground concrete pipe would be more satisfactory in all respects than either and have longer life than wood structures, but their high first cost, amounting to about double that of wood, has been sufficient to deter berry growers from installing them for the comparatively short time land is usually kept in irrigated small fruits, and they are seldom found in practice. The use of iron surface pipe is not extensive in the irrigation of small fruits.

Small earth ditches are used extensively in berry irrigation in lower San Joaquin Valley. They are also found in Placer County and in a few sections of southern California. Conditions encouraging their use are the low first cost and an ample water supply.

Wooden flumes are very commonly found in Pajaro Valley, Santa Clara Valley, and the southern California berry centers. In Pajaro Valley rectangular boxes are used, the main flumes being 12 by 14 inches and the laterals 8 by 10 inches, outside measurement; i.e., the box is constructed of three pieces of 1-inch by 12-inch or 1-inch by 8-inch lumber, as the case may be, the sides being nailed outside the floor and making the inside measurement 11 by 12 and 7 by 8 inches, respectively. Small cleats are nailed across the top at intervals of 2 to 8 or 10 feet to brace the sides, and occasionally these braces extend completely around the flume. The inside of the flume is partially or wholly painted with tar or the joints are covered with tarred paper to insure water-tightness. Sometimes pieces of lath are nailed outside over the vertical joints. Wherever possible the flume box is laid on the ground, but when crossing a swale simple wooden supports are used (fig. 5). The main flume between the berry field and pumping plant, where it must be raised in order to provide sufficient grade, rests upon a more elaborate trestle (fig. 6), consisting of 2-inch by 4-inch bents and caps, braced with 2-inch by 4-inch cross-pieces, set about 8 feet apart. Diagonal braces are provided where necessary to give additional strength or to supplant the horizontal braces. For crossing deep, narrow gullies, suspension bridges with triangular trusses are in use. Inverted siphons are frequently placed at road crossings. The grade of the main flume is usually about 3.5 inches in 100 feet, and of the laterals 1 to 2.5 inches in 100 feet.

In some parts of Santa Clara, San Fernando, and San Gabriel valleys and elsewhere a V-shaped flume is more common than the rectangular flume. This is made of two 1-inch by 12-inch or 1-inch by 8-inch timbers joined at right angles and braced at the top or com-

pletely around by cleats nailed at intervals of a few feet. The construction of this type is somewhat simpler and the liability to leakage less than in case of the rectangular form, but some side support must be given the V-flume even when it is laid flush with the ground. With very small heads of water this type of flume is the more economical, owing to the smaller quantity of lumber required.

At the lateral turn-outs from the main flumes, two cleats are nailed at each side of the lateral to form grooves into which the slide-gate may fit.

Galvanized iron surface pipe, 2 inches in diameter, is in limited use in bush-berry fields in the Sierra Nevada foothills, the pipe sections

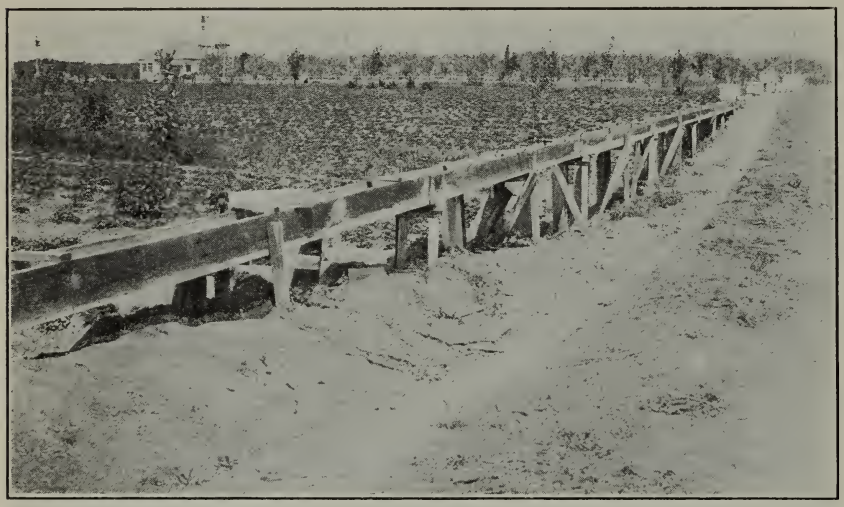

Fig. 5.—Flume trestle crossing swale. Simple wooden supports are used where the flume is close to the ground.

being disconnected as convenient and the water allowed to run into a small group of furrows at one time. Cast-iron pipe is likewise of limited general use, but is found locally in most of the berry fields in the Montebello district of Los Angeles County, where water is supplied under pressure from underground mains and the quantities used determined by meter. This pipe is commonly 2 inches inside diameter and is laid on the ground surface along the upper ends of the irrigation furrows, the flow into the various laterals being controlled by valves.

Some growers in the Moneta district of Los Angeles County have earth ditches lined with 1-inch by 12-inch lumber on the side nearest the beds, the lumber being held in place by stakes. This type of dis-

tributary does not prevent seepage losses, but it prevents erosion of the sides of the furrows and better regulates the quantities of water turned into the furrows than if no facing were provided, at the same time eliminating two-thirds of the cost of a flume.

When earth ditches are used metal dams or tappoons are set in place for diverting the water into any desired number of furrows, and when these furrows have been irrigated the tappoon is carried farther down the ditch for the next set. Obviously it is necessary to close the heads of the furrows as they are watered. Sometimes short pieces of 1-inch iron pipe are laid through the ditch bank to admit water to the furrows. Small division boxes with slide-gates are placed at the junction of main ditch and laterals.

Fig. 6.—Flume trestle at pumping plant. When the pumping plant is located at a low point in the field or at some distance from the field, the trestle must be raised high enough to provide the necessary grade.

Water is released from the wooden flumes through holes or cuts of varying sizes (fig. 7). In Pajaro Valley and parts of Santa Clara Valley the holes are usually 3 inches in diameter, with the lower edges made flush with the bottom of the flume, and fitted with wooden plugs partially wrapped with cloth to insure tight fitting. Sometimes rectangular cuts are made, plugs for which are the pieces that were sawed out, wrapped with cloth. In parts of Santa Clara Valley and in southern California 1-inch auger holes are made in the side near the bottom, one hole for each furrow, and either wooden or cork plugs or hinged wooden doors are provided for regulating the flow. In the

case of V-shaped flumes also, 1-inch auger holes are bored near the bottom and fitted with plugs or corks. With large heads of water two or three such holes are grouped for each furrow, this same practice being followed in earth ditches lined on one side with lumber as above described. To prevent washing, the outlets should be placed as close to the ground as possible.

Dams in rectangular flumes consist of short pieces of lath placed one above another on edge and made long enough to fit tightly into the flumes. Sometimes longer sticks are merely laid against the cleats, nailed at intervals across the flumes, particularly in the case of V-shaped flumes on account of their inconvenient shape (fig. 8). This

Fig. 7.—Irrigating from rectangular wooden flume. This shows the rectangular openings in the flume, and also the more commonly used circular holes fitted with wooden plugs.

is a makeshift practice, however, and at small additional cost it would be possible to have slide-gates at convenient intervals in either type of flume by cutting grooves or nailing cleats on two sides. These gates could be raised or lowered in a rectangular flume to permit the desired quantity of water to pass, and in case of a V-flume triangular gates of varying height could be used to allow for the desired overfall.

In the case of the cast-iron pipe used at Montebello, holes one-fourth to five-sixteenths inch in diameter, one for each furrow, are provided as outlets. These holes are fitted with wooden plugs. The flow of water in the pipes is controlled by valves.

Assuming the length of furrows to be 200 feet and not counting main supply conduits, there will be required per acre for an average shaped tract about 525 board-feet of 1-inch lumber, of which 125 board-feet is for the 12-inch main flume and 400 board-feet for the 8-inch laterals. At $25 per thousand feet the cost of lumber will amount to about $13 and labor will cost about $6 or $7, providing the flume is laid on the ground, making the total cost of flume installed approximately $20 per acre. Any amount of trestle required will increase the cost correspondingly because of the added amount of lumber and greater expense of fitting. If water is conveyed from a pumping plant located outside the tract, as is often the case, there should be added to the above figures the proportionate cost of installing the flume leading from the plant to the tract, which will depend upon the added length of flume and amount of trestle-work required.

The cost of a 12-inch V-shaped flume will be about the same, but an 8-inch V-type installed under the same conditions will cost $14 or $15 per acre.

MAKING THE FURROWS

The types of furrow systems found in California berry fields are described later. Only the process of making them, which is the next step in the preparation of the field, will be considered here.

In Pajaro Valley, where the strawberry furrows are very broad, the general practice has been to make them with a shovel. On a pole some 30 feet in length are made pairs of marks representing the width of the furrows, with the distance between the pairs equal to that desired between furrows. The pole is laid down successively along the supply ditch or flume and stakes are set at each mark, and the process is repeated at the foot of the furrow spaces, usually 150 to 300 feet away. Strings or wires are then stretched taut from each head stake to its corresponding stake at the foot so that the furrows lie marked out on the ground. A man then goes down the furrow spaces with a shovel and throws alternate shovelsful right and left to equalize the furrows and ridges. The cost of this operation, including smoothing the ridges afterwards, is $15 or more per acre. More recently, however, in Santa Clara and Pajaro valleys horse-drawn implements for making ridges have come into use because of the smaller cost. A typical implement of this kind consists of three iron V-scrapers, the sides flaring outward toward the rear, these being fastened together, abreast, the desired distance apart, the whole hung from two wheels in front and from one at the back, and with two upright rachet levers for raising or lowering

the "V's" with reference to the wheels (fig. 9). This implement is drawn by four horses, the driver standing on a platform at the back and adding his weight to the machine. This of course makes three furrows at one time. The ridges are subsequently properly shaped and smoothed with hoes and spades. Sometimes, however, the ridging is done with a disk-harrow drawn by two horses, the two disks on each side being set at such an angle that the earth is thrown into a ridge in the center, the finishing being done by hand. Other growers do the work with shovel-cultivators. A small shovel is attached to the back of a V-shaped cultivator, with ropes stretched to keep it in line, the teeth stirring up the soil and the shovel throwing it to both sides. Later

Fig. 8.—Irrigating from V-shaped wooden flume. The water is turned into the furrows through 1-inch auger holes near the bottom of the flume.

along the furrow thus marked out a broader shovel is drawn to widen and complete it, the ridges then being smoothed with hoes. This finishing work is facilitated in any case by stretching wires or ropes along the edges of ridges to mark the desired width and then working into them. The cost of these various methods ranges from $2 to $6 or $7 per acre. Their disadvantage as compared with the hand method lies in the difficulty in adhering to a perfect alignment, but the lessened cost is an important factor.

In some places the rows are measured at the head with a tape instead of with a marked pole. Marking the furrow centers is sometimes done with a wheel-barrow, though the liability of variation from

a straight line is great. Again a sled, with runners adjusted to the proper width, may be used, and a variation of this consists in having the runners spaced twice the desired width with a chain dragging in the center to make the third mark. By moving this up and down the field with the outside runner following closely a mark already made, the proper alignment may be maintained.

Where the furrows are not so wide, but are deeper, they may be readily made with a one-horse plow by going back and forth along the mark to the desired depth. Very small furrows are sometimes made with a hand plow or even with a hoe. The ridges are thrown up to a greater height than is ultimately intended and later smoothed down.

Fig. 9.—Ridger used in Irvington berry district. Each of the three "V's" scoops out a furrow. The implement is drawn by four or six horses.

This finishing may be readily done with a V-shaped ditcher or crowder adjusted to the final width of the furrow and having horizontal wings to smooth the surface of the ridges, which is the practice in the Florin and San Joaquin County sections. In the Moneta district of Los Angeles County the newly-made furrows are first harrowed with a V-shaped cultivator to prepare the furrow bottoms, and then a ridge smoother completes the tops and sides of the beds. This ridge smoother consists of three boards about 3 feet in length fitted together in such widths and at such angles that the completed form corresponds exactly to the desired shape of the ridge when completed. Being drawn by one horse and with the driver standing on it, this implement molds the ridges to their final form.

There is also in use in the Gardena-Moneta section an ingenious scoop-scraper for the removal of minor irregularities in furrows (fig. 10). This scraper consists of a 2-foot section of 12-inch well-casing opened and spread into a semi-circle, blocked with wood at the back end and braced across the top with a stick at the front. At the back is a handle 2 feet long extending from the two sides, and attached to the block of wood is a very short handle, the former for bearing down and the latter for lifting. The implement is drawn by one horse. Sometimes the scoop is used before harrowing the furrows, and again not until water has been turned into the furrows and the small irregu larities in grade are more discernible. Very small quantities of eartl

Fig. 10.—Scoop-scraper for furrows. This is used for correcting minor irregularities in the grade of furrows. The long handle is for bearing down, and the short handle for lifting. It is drawn by one horse.

may be easily handled in this way and a more nearly perfect grade secured.

Provision is usually made for dams of some kind in the furrows where the soil is too heavy to permit of rapid penetration of irrigation water and where the grade is such that water might run off too rapidly. In some cases these dams or checks are of soil, often covered with newspapers or cloth to prevent their washing away, and placed every 60 to 80 feet or more apart in the furrows, serving to hold back the water and to permit it to soak into the ditch banks (fig. 11). Again a wooden dam may be used, with a piece cut from the top to permit water

to flow over into the next section (fig. 12). The washing of the soil caused by falling water may be avoided by imbedding a few stones close to the dam. These checks are used only in large furrows having some grade where considerable quantities of water are turned in, and have no application to the practice of making small furrows and turning into them only enough water to reach the ends.

The construction of a small drain or run-off ditch is necessary at the ends of furrows where the soil does not absorb rain water as it falls and where consequently there is danger of flooding. There is less liability of damage from this source during the irrigation season because of the possibility of regulating the amounts of water in furrows; hence the ends of the furrows are opened in winter and closed in summer.

With the completion of the ridges and furrows the field is ready for planting.

TRELLISES

Bush berries of the trailing type are trellised, and even those of the upright type are usually provided with some form of support because of the weight of the canes when loaded with fruit. The trellis consists of posts 2 inches by 4 inches, more or less, in dimension, 3 to 5 feet high, and set from 10 to 30 feet apart, with double wires stretched one above another or abreast. Such trellising costs from $10 to $25 per acre in place, depending upon the extent of vegetation and resulting strength of materials necessary to support it.

SETTING PLANTS

In setting strawberry plants a spade, dibble, or trowel may be used. Often a line is stretched along the bed at the proper distance from the side and the planter goes along this, estimating the distance from plant to plant. In sections where very small furrows are made the plants are sometimes set out before the furrows are made. A marker is used in San Fernando Valley consisting of a number of thinly-sharpened pegs projecting downward from a timber at intervals corresponding to the distance between the rows, with a handle in the center, and all usually of very light construction. This is drawn down the field by a man to mark out the plant rows. After setting the plants the furrows are made with a hand plow. In some instances plants are set out in a trench made by a plow. Bush berries are set in holes made with a spade or in a trench, and if regularity of spacing is desired the distances are measured.

Setting out the strawberry plants costs $8 to $10 per acre. The plants themselves vary in price, from $2 up to $15 or $20 per thousand. Most of the varieties grown commercially in California cost from $2 to $6 per thousand. The number of plants originally set per acre ranges from 12,000 to 18,000 or 20,000, and the acreage cost for plants usually ranges from $20 to $50, because reductions may be made when plants are supplied in very large quantities. Setting out bush-berry plants costs about one-half as much as setting out strawberries. They are spaced farther apart and fewer plants are used—about 800 per acre for blackberries, up to 2500 for raspberries and currants, with loganberries and dewberries at intermediate figures. The California

Fig. 11.—Earth dams in furrows. These are placed at intervals to hold back the water where the grade would otherwise cause it to run off too rapidly.

bush-berry varieties range in price from $5 to $35 per thousand, making the acreage cost from $20 to $60 for plants, or about the same as for strawberries.

FURROW SYSTEMS

Only one method of irrigating small fruits is in use in the commercial berry centers of California, and that consists in applying the water in furrows. As a rule the plants are set on raised beds or ridges and the water is allowed to seep into the sides, but in a few places the berry plants are placed on the general level of the field and the water

is run in very small furrows made after planting. There are of course some exceptions to the one general method of irrigation. For instance, in the southern part of the state a few growers of nursery stock and berries, vegetables and berries, and small fruits and flowers are using spray systems of irrigation, but for small fruits alone such systems have not at this writing come into extended use in commercial plantations in California. The depressed-bed method, in which the plants are grown on level areas inclosed by levees along the tops of which small irrigation ditches are run, although found in truck gardens near the large cities, does not appear in strawberry fields at the present time.[1]

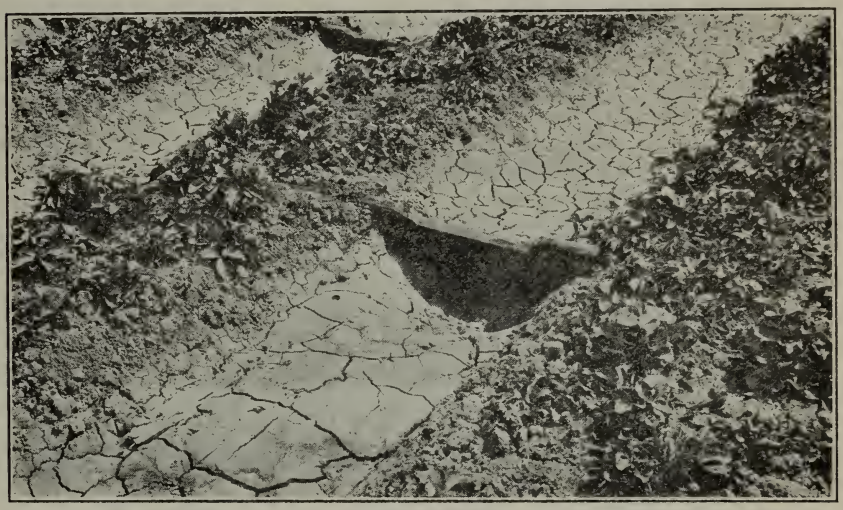

Fig. 12.—Wooden dam in furrow. The cracks in the soil are the result of failing to cultivate after irrigating.

Within this general method of irrigation by furrows are the two divisions spoken of above, the raised-bed and level-planting systems, and the former may be further subdivided into three classes for strawberries and two for bush fruits, differing mainly in the relative locations of furrows and berry rows. These have been termed the single-row system, the matted-row system, and the double matted-row system of irrigating strawberries, and the single-furrow and double-furrow systems of bush fruits. Thus the differences in the strawberry systems relate mainly to the width of the beds and consequent character of plant rows on the beds between furrows, and in the bush-berry

[1] The merits of various methods of garden irrigation are discussed in U. S. Dept. Agr., Farmers' Bull. 138, "Irrigation in Field and Garden."

systems to the number of furrows between plant rows. Within these groups are also variations in dimension. Whenever the term "bed" is used herein it is taken to mean the ridge between two furrows.

Furrows in berry fields are usually 200 to 250 feet in length. Often they are made level from end to end, or again are given a grade of upwards of 3 inches in 100 feet. Where large heads of water are turned in and the desire is to fill the furrow and to allow the standing water to seep into the sides, the only purpose subserved by a grade is to induce rain water to run off where the soil does not absorb it readily, and in such case dams as described on page 14 must be placed in the furrows at intervals to hold back the irrigation water. Where the soil is sufficiently porous to absorb rain water the level furrow is preferable. Small furrows in which very small streams are to be run are laid on a grade in order to permit the water to reach the ends.

FURROW SYSTEMS FOR STRAWBERRIES

The raised-bed method is by far the more prevalent of the two practices and in the following descriptions its several subdivisions will be given equal weight with the level-planting system.

Single-row system.—This is probably less in use than either of the other raised-bed systems and certainly less than the ordinary double-row system. Fields are laid out on this plan in Los Angeles and Orange counties, Santa Clara Valley, at Galt in Sacramento County, and doubtless elsewhere. In one field of this type visited the furrows are 2 feet apart from center to center, and the ridges and furrows are of equal width, the furrows being about 6 inches deep. The distance from center to center of beds is sometimes 22 inches, or as much as 34 inches, in the latter case the width of the furrow exceeding that of the ridge, which is an uneconomical practice because of the lessened area given to the plants. The depth of furrows likewise varies. It is seldom greater than 6 inches under this system, but is often only 3 or 4 inches, the determining factor being the water supply available and the head to be run in each furrow.

Very often the plants are grown as "singles;" i.e., all runners are cut off as they appear and only the original or mother plants are allowed to grow. Sometimes one runner plant is set between adjoining originals, however, especially where the latter are planted far apart. This distance between plants is governed by the variety and by the financial means of the grower. Varieties that make large plants and that produce many runners require greater spacing, and a grower

whose means make imperative as small an initial outlay as possible usually buys a minimum number of strawberry plants and depends upon the runner plants to supplement the stand. Consequently this original spacing is found to vary from 6 inches to 4 feet. In a large field at Strawberry Park, Los Angeles County, plants were set out 4 feet apart in the center of the bed in the first instance and two rows of four runner plants each were made between adjoining originals, resulting in an ultimate distance of about 10 inches between plants.

In soils which permit of limited lateral penetration of irrigation water this single-row system is preferable because of the narrower beds and greater opportunity for irrigation water to reach the plant roots from the two furrows. Objections made by some growers are that the greater proportion of wetted surface gives more opportunity for baking and that the narrower ridges dry out too quickly; also that in very light soils the sides of the ridges are eroded and plant roots thus exposed to injury. The first objection may be partially overcome by cultivation, and the second is not serious in heavier soils. On the other hand, an advantage of the narrower beds lies in the greater area that may be cultivated with a horse and the consequent elimination of much expensive hand work.

Matted-row system.—The matted-row system differs from that just considered in the greater width of beds between furrows and the covering of the beds with plants instead of limiting the plants to one row on a narrow bed. This is the most widely used method found in California for strawberries. It is universal in Pajaro Valley and is largely in vogue in Santa Clara Valley and southern California. The field shown in figure 13 is a typical Pajaro Valley field of this class. The ridges or beds are spaced 54 inches from center to center, the ridges 32 inches wide, and the furrows 22 inches wide and from 3 to 6 inches deep. The beds are level from side to side. The furrows vary in length from 150 to 300 feet, 200 feet being probably most general. At the end of a bed of such length another supply flume heads another similar bed.

In the matted-row system the plants are originally set out in double rows on each bed, the rows being 20 inches apart and the plants 10 to 22 inches apart in the row, depending upon the variety. For instance, Malindas are usually spaced 10 or 12 inches apart and larger varieties like the Klondike about 20 inches. From these mother plants all runners are cut off during the first year, except two or three which are set to fill the intervening spaces, thus giving a single matted row on each bed and covering the entire ridge with foliage.

There are variations from these dimensions, however. Sometimes the distance from center to center is only 42 inches. In many parts of southern California the distance is 36 inches, with the ridges and furrows of proportionate width, or about 21 and 15 inches, respectively. In other places the distance from center to center is 34 or even as short as 28 inches. The 54-inch dimension is followed in parts of Santa Clara Valley.

In Pajaro Valley there is a considerable area of hillside plantings where the rows follow the contours. The distance from center to center of furrows is greater than in level fields, being 66 inches usually, or a foot greater. The slope of the ridges from side to side is greater than

Fig. 13.—Strawberries under matted-row system. Two rows of plants are originally set out along each bed and the runner plants fill the intervening spaces, making finally one matted row between two irrigation furrows.

the general slope of the hill and the ridges are banked up so that the furrows are level and symmetrical from side to side. It is quite necessary that the upper side of each bed should be well banked, else in cultivating the furrow, soil will be thrown down upon the plants. These hillside plantings are satisfactory where the soil is good and where it is carefully prepared, and, also, where there is good underdrainage.

The matted-row system with its greater width of beds has the advantage of a smaller number of furrows to take care of. It is adapted to soils where conditions are favorable for lateral penetration of water by capillarity or because of an underlying hard stratum, and

the beds should not be made so broad that the moisture from the two furrows is unable to meet within a short time after irrigation.

Double matted-row system.—The points of difference between this system and the ordinary matted-row system just described are the division into two independent rows of plants on a bed, the resultant greater distance between irrigation furrows, the greater depth of furrows, and the differing functions of the alternate spaces between plant rows. Figure 14 represents a typical field of this type at Lodi, in San Joaquin County. The distance from one furrow center to another is 6 feet, and the furrows are 12 inches deep. The plants are originally set out in double rows 3½ feet apart and 1 foot apart in the row. From each of these plants two to three or four runners are made to take root, largely set in from the furrow side, although some plants hang out over the furrow. When the two parallel rows on a raised bed have completely formed there is a bare space some 18 inches in width between. The result of this system is parallel matted rows 3 feet apart from center to center, with irrigation furrows and level bare strips in alternate intervening spaces. The purposes of these two classes of intervening spaces are altogether different; that is to say, the furrows are used for carrying water only, whereas the bare strips on the beds are cultivated, instead of the furrows, and they further serve as paths for pickers to walk in. The furrows are made quite level from end to end, and about 100 feet long. In some of the fields the distance from center to center of furrows is 5 feet instead of 6, and in other localities it is as great as 7 feet.

An adaptation of this system to an inter-cropping of berries and vines is found in the Florin district, in Sacramento County, and is practically universal there in berry fields. The strawberries are incidental to the vineyard and are planted in order to provide an income while the vines are maturing. The grape vines are set 8 feet apart each way and the irrigation furrows are 1 foot from the vines, but are only made on one side of them. Thus the distance from center to center of furrows is 8 feet. The furrows are 12 to 18 inches wide and 1 foot deep. On each side of the "lands" between the vines a row of strawberry plants is set out, one of these rows being directly in line with the vines. The plants are placed upwards of 32 inches apart in the row, and from these original plants six or seven runner plants each are formed. The result is the same as in the Lodi, or double matted-row system just described, with a bare space of some 18 inches between the two resulting rows on each bed. Sometimes the strawberry plants are set closer together in the rows, say 14 to 18 inches apart,

and fewer runner plants are allowed to take root. The number of plants originally put out, as heretofore stated, is usually dependent upon the means of the grower. The beds in the Florin section run east and west and the vines occupy the north edge of the beds, in order to give the greater sun exposure to the berries. It is the experience of growers that the strawberry plants along the south edge produce from two to two and one-half times the quantity of fruit that is taken from those on the north.

The double matted-row system, with its variation in use at Florin, is especially adapted to porous sandy soils overlying hardpan or heavy clay subsoil, for rapid lateral percolation is assured and evaporation

Fig. 14.—Strawberries under double matted-row system. Two independent rows of plants are formed on each bed between furrows. The furrows are only for irrigating, and the bare space between plant rows on the raised bed is for cultivating and picking berries.

losses are likely to be small, owing to the smaller cross-section of the furrows. The system has an added practical value in affording a dry place for pickers to walk while water is running in the furrows. In a field of this type at Florin a boring made in the exact center of a bed one week after irrigation disclosed an abundance of moisture above the hardpan, which was 30 inches from the surface at this point, thus indicating that where such soil conditions are encountered an extra furrow through the center of the bed is unnecessary. However, in a very heavy soil where capillary movement is sluggish, or in a soil so porous that lateral penetration of water is limited to a few inches, this system would doubtless be found inadequate.

Level-planting system.—Under this system no raised beds are made, but the plants are set out on the general level of the field and small furrows are afterwards made with their tops higher and bottoms lower than the surface around the plants. The essential difference between this and the raised-bed method is that with the former the furrows may be destroyed by cultivation and if so must be remade before another irrigation, thus permitting flat culture, whereas in the methods heretofore considered the beds and furrows are made permanent during the life of the planting.

The level-planting method is not in wide use. Instances of it are found, however, in Sonoma and Placer counties, and in San Fernando Valley. In the foothills of Placer County the furrows are run directly down the slope of the hill, unless the latter is too steep, and are placed close to the plant rows. Where the ground slopes laterally also, the furrows are run on the upper side of the rows rather than below them. The plant rows are usually spaced 36 inches from center to center and the plants are grown as "singles" 12 to 16 inches apart in the row. The furrows are about 4 to 6 inches wide and 2 inches deep, and unless cultivated down and renewed from time to time erosion tends to increase their depth. This method is also found on level lands in San Fernando Valley. The plants are set in single rows 19 to 20 inches apart and about 11 inches apart in the rows, with a furrow 9 inches wide and 3 inches deep directly between the rows. In Sonoma County under favorable conditions strawberries are often unirrigated, being laid out in single rows 3 feet apart and upwards of 18 inches apart in the row, on a flat-culture basis.

FURROW SYSTEMS FOR BUSH BERRIES

Owing to the much greater distances bush berries are set apart, the question arises, not as to how many rows of plants to place between two furrows, but what number of furrows to use between plant rows.

Single-furrow system.—Where only one furrow is used between plant rows on raised beds it is usually broad and shallow. Where the rows are 6 feet apart from center to center the raised ridge is about 2 feet wide and the furrow is 4 feet wide and 4 inches deep, and level from side to side. An advantage claimed for this is the elimination of a dry area in the space between rows. The spreading of the water in a thin sheet, however, increases the danger of evaporation losses. This method is found in parts of southern California.

There is considerable variation in the distance between bush-berry plants, ranging for blackberries from 3 to 8 feet apart in rows, and

from 5 to 10 feet between rows. Probably the average distance for the most widely grown varieties is 6 by 8 feet. Dewberry bushes average 4 feet apart in rows which are 7 feet apart. The average practice for loganberries is to set them out 5 feet apart in rows 6 feet apart, although practice varies in different localities and with different soil types. Raspberries are usually planted closer together in the rows, generally 3 feet, and about 6 feet between rows. Gooseberries, which are grown to a very limited extent in California, were set 4 feet apart in rows 6 feet apart in the few instances noted, and currants about 2½ by 4½ feet.

Fig. 15.—Young loganberries under double-furrow system. The intermediate ridge between plant beds provides a dry path for pickers while water is running.

Double-furrow system.—The use of two irrigation furrows between rows goes with growing the bush berries on raised beds. The furrows, which are small, are made close to the plant rows and between them is a low ridge which provides a dry path for pickers to walk on while irrigation is in progress. In a typical field where the plant rows are 8 feet apart, the main plant ridges are 2 feet wide, intermediate ridges 3 feet wide, and furrows each about 18 inches wide and about 8 inches deep. The subsidiary ridge lies several inches below the surface of the plant beds. This system, which is very general in southern California, is better adapted to wide spacing of plant rows than is the plan of having one broad furrow, because of the necessarily great width of the latter, and the greater heads of water necessary; and by having

a furrow on each side of the ridge the plant roots are more generously supplied with water than in the next method considered.

Level-planting system.—In connection with setting bush berries on the general level of the field one small furrow is often provided for their irrigation. This is placed close to the row on one side or the other. The furrow is usually made 12 to 18 inches wide and about 6 inches deep. This is the plan generally followed in sections with more abundant rainfall than that of southern California and where less irrigation is required. In the Placer County foothills the rows are usually run directly down the slope, with a furrow 4 inches wide and 2 inches deep close to each row. Where bush berries are not irrigated, as in Sonoma County and parts of Santa Cruz County, no attempt is made to grow them on raised beds.

APPLICATION OF WATER

The water supply for berry irrigation must be a dependable one throughout the dry season and particularly while fruit is being produced. This applies in greater measure to strawberries than to other small fruits because bush-berry plants are the more drought resistant. Only small quantities of water are needed for strawberries at any one time, but it is needed often, and the lack of water for a protracted period during the summer may prove fatal to the plants or at least impair their crop-producing powers for another season. Hence the commercial strawberry grower whose field is located under a canal system with erratic water supply often needs to supplement such supply with a pumping plant.

As a matter of fact pumping plants furnish most of the water used in the large berry centers of California. They are usually small plants, for the acreages and heads of water used are small.[2] In the foothills of Placer County gravity water is used, delivery being continuous to each irrigator throughout the season and thus favorable to berry irrigation.[3]

The amount of water applied to strawberries under present practice in California is much greater than that applied to bush fruits. Strawberries bear for a longer time each year and are shallower rooted, and although the frequency of application could be lessened by more attention to the advantages to be derived from cultivation, nevertheless the

[2] For the size and cost of a pumping plant for a given acreage, see Cal. Agr. Exp. Sta. Cir. 117, "The Selection and Cost of a Small Pumping Plant."

[3] For a description of irrigation conditions in this section see Cal. Agr. Exp. Sta. Bull. 253, "Irrigation and Soil Conditions in the Sierra Nevada Foothills, California."

moisture in the limited feeding zone of the roots requires more frequent replenishment and the plants are more ready to show signs of distress.

STRAWBERRIES

Strawberries require ample moisture in the soil constantly during the growing season and particularly while bearing fruit; hence it is obvious that varieties with a long bearing season need more water over a longer period than so-called "one-crop" berries, for after the latter have ceased to produce fruit they need less for the development of the plants alone. As the root system is usually confined to the first 12 or 14 inches in depth and seldom extends below 18 inches, the upper 2 feet of soil must be kept moist. Hence arises the necessity for frequent light applications of water in amounts sufficient to replace moisture lost by evaporation and withdrawn by the plants, but not for so great a supply of water that an excess is permitted to seep beyond reach of the roots. Ordinarily in practice no particular test other than dryness of the surface soil and a brown tint to the leaves is used to determine when this need for irrigation exists. Many growers believe that the supply of berries increases with the amount of water applied, and due to this belief comparatively few plantations are found where with an ample water supply at hand the plants are allowed to reach a stage of distress at any time during the year. Although too little water causes the berries to be few and small, an excess often renders the fruit soft and unfit for long shipment. In some sections of California, notably the Sebastopol district of Sonoma County, many strawberry fields are not irrigated. Conditions making possible strawberry production without irrigation in the Sebastopol district are the heavy winter rainfall and soil conditions favorable to the retention of moisture during a large part of the dry season, but yields are reported to be lighter than those from irrigated fields, and in a dry autumn the plants suffer and are rendered less productive the following season. Yet for economic reasons, such as the high cost of irrigation and difficulty of competing with certain other sections, irrigation is often locally considered not justified.

Where strawberry plants are grown on raised beds, which as before stated is the common practice in California, it has been found that the entire ridges must primarily be wetted, but that it is not well for the surface of the ridges to be kept damp because fruit coming in contact with damp soil usually spoils, and further because such surfaces on drying tend to become baked or checked. The crust may of course

be broken by hoeing, but it is obviously unnecessary and undesirable to start with. Consequently in order to wet the ridges thoroughly without moistening the immediate surface layer, the practice is to carry the water in the furrows almost to the ridge tops and to depend upon lateral seepage and capillarity to distribute the moisture throughout the ridges. To be able to run the water in this way a very careful preparation of the land is essential (see p. 2).

The number of furrows watered at one time is dependent upon the method of irrigating and upon the head available. That is to say, if the method is to fill the furrows quickly, to take the head elsewhere, and to allow the standing water to seep into the banks, the number of furrows a single head is turned into is not so great as if it is allowed to run into the furrows for a long time and to feed slowly into the soil. The former practice is followed in sections like Pajaro Valley and Sacramento County where capacious furrows are the rule. With heads of water of 90 to 200 or 300 gallons per minute some three to nine furrows are watered at one time and the amount turned into each furrow ranges from 10 to about 30 gallons per minute. The number of furrows is sometimes changed to suit the convenience of the irrigator. If he has other work nearby he doubles the number of openings in the flume and thus secures more time between changes from one set of furrows to another. With this method it is necessary that the furrows be level from end to end, or else that dams or checks be placed at intervals to hold back the water, as shown on page 14, in which case a fall of 1 to 3 inches is given in 100 feet of length. Level furrows are desirable only in well-drained soil.

The method of running the water for long periods of time in small furrows is followed in Placer County and in some other sections. With a stream of 30 gallons per minute upwards of twenty-six furrows are watered at one time, with thus about 1 gallon per minute in each furrow, and the same ratio holds good for smaller heads. Usually the amount is gaged by the quantity necessary to reach the end of the furrow without waste, and this quantity once established is permitted to run for 12 hours or more. Some very steep slopes are irrigated in this way. On fairly heavy soil near Galt, from thirty to sixty furrows are watered at one time with a head of 90 gallons per minute, or 1½ to 3 gallons per minute in each furrow. The grade is approximately 1 inch in 100 feet. The water is run for about 10 hours in each furrow. In San Fernando Valley on sandy loam soils with but little grade, upwards of sixty furrows are sometimes supplied at one time with a reported flow of 60 miner's inches and the water run for a long time.

The irrigation season extends in most places from the cessation of spring rains until some time in the fall. If the dry season is protracted in the fall, late bearing varieties are irrigated sometimes until December, but plants that have ceased to bear are usually not watered so late. Conditions are different in most sections of California from the mountain states where the season is much shorter than here and where irrigation must be suspended to permit the plants to go into dormancy before freezing weather sets in. The frequency of applying water varies from time to time during the season. Factors governing this in practice are the length of the bearing season, the weather, and the convenience of the irrigator. In general, irrigation occurs most

Fig. 16.—Irrigating strawberries under matted-row system. Water is turned into three to nine of these large furrows at one time.

frequently during the summer months when the bearing season is at its height and hot weather is prevalent, and as pickings then occur oftener the applications are often timed to follow them immediately. According to different practices the intervals at which the field is irrigated depend also upon soil type and frequency of cultivation.

In Pajaro Valley the usual practice is to irrigate immediately after picking, which means every ten days or two weeks in early spring and in the fall months, and every week at least during the summer. No particular test governs the time of irrigating, but it is largely a matter of convenience. However, if a particularly hot spell occurs during the summer more frequent irrigations are the rule, sometimes as often as

every four or five days. A great many days in summer are foggy and in some cases this has its effect on the frequency of irrigation, for the soil naturally remains moist a greater length of time and longer periods are allowed to elapse between waterings. Some growers in this section irrigate the lighter soils every week and heavier ones every two weeks.

The practice in the San Juan section of San Benito County closely follows that in Pajaro Valley.

In Santa Clara Valley strawberry fields are irrigated each week in summer and every two weeks in spring and fall.

At Galt, in Sacramento County, on heavy retentive soils the irrigations are comparatively few, averaging eight times in a season, or every two weeks during hot weather. In the Florin district of this county, however, on lighter soils berry fields are irrigated as a rule every week through the hot weather and every ten days when the weather is cooler. The San Joaquin County practice is the same. If the weather is unusually hot or if a north wind is or has been blowing, waterings often take place at intervals of four or five days.

In Placer County strawberries are not irrigated much before the fruiting season, but while the plants are bearing they are watered about twice each week. After the first crop no more water is applied than absolutely necessary to keep the plants alive until about two weeks before the second crop comes on, when frequent irrigations are resumed.

In typical sections of Orange County heavier soils are irrigated every ten or twelve days throughout the dry season and lighter sandy soils more frequently, sometimes each week. During the fruiting season water is sometimes applied every five days.

In the Burbank section of Los Angeles County on sandy loam soil the water is applied as often as every second day during the fruiting season. In San Gabriel Valley on light soil it is applied every four or five days. In the Gardena-Moneta district strawberry plantations on heavy clay soils are irrigated each week or ten days, and on light soils twice a week in the summer and less often in spring and fall.

In some southern California districts growers follow the practice of irrigating in alternate furrows and picking from the dry furrows at the same time. At Montebello, for example, one grower irrigates every three days, turning the water at one time into one set and the next time into the other, and has his pickers in the dry furrows simultaneously. This amounts to a complete irrigation and picking every six days. The same practice is followed by some berry growers in the Moneta section and elsewhere.

To sum up, light soils generally are irrigated at intervals of three to seven days in summer and ten to fourteen days in spring and fall, and heavy soils every week or every two weeks in hot weather and less frequently when cooler.

First-year plants require less water than older ones. They are smaller and the amount of fruit produced is slight—barely sufficient to pay for picking. Still some growers irrigate fully as much during the first year as later. Sometimes young plants are irrigated as frequently as older ones but with less water, the water being run only in the bottoms of the furrows. The time of applying the first water depends upon whether plants are set out early or late.

The duty of water for strawberries under present practice is found to be low as compared with most staple crops, being estimated to range from 3 to 5 acre-feet per acre in most of the important centers of the state. In some places by judicious use and conservation of water the seasonal depth is kept below 36 inches, but the general practice seems to be to apply more. Individual applications are necessarily light, ranging from 1½ to 2 or 3 inches in depth per irrigation and averaging probably 2 inches. Thus with the depth applied at each irrigation remaining practically constant at a figure which it is difficult to lower as a practical undertaking, the question of increasing the duty of water apparently becomes one of limiting the total number of irrigations in a season.

In a farming industry which involves the application of so much water as strawberries the problem of drainage assumes importance. Low-lying heavy soils are apt to become waterlogged sooner or later, which of course means poor plants and diminished yields of fruit, if not loss of plants absolutely and injury to the soil structure. Surface drainage during the rainy season is also necessary to avoid flooding the plants, and to take care of this and also any excess of irrigation water small drainage channels are often provided at the ends of furrows. Sometimes excess irrigation water is utilized by being carried into other furrows.

BUSH BERRIES

Bush fruits differ from strawberries in their irrigation needs in that they are deeper rooted and thus can draw upon a greater depth of soil; hence are better fitted to withstand periods of drought. In some sections of California they are not irrigated at all—in the Sebastopol district, for example, where there are very extensive plantings of blackberries and some of loganberries. With soil conditions

favoring the retention of moisture and with proper cultivation the rains of the winter seem to prove sufficient for a year's production of these berries. In the cool bay climate of Alameda County currants are produced likewise without irrigation. In some other sections, however, where bush berries can be and are grown without irrigation, the growth of the plants and the quantity of fruit are often increased with artificial applications of water to such an extent that increased profits justify the installation of irrigation systems.

The time when blackberry, raspberry, loganberry, and other such plants need moisture mostly is while forming fruit, and after the bearing season is over a small amount suffices to maintain the plant growth. If the moisture supply is short the fruit tends to be small, dry, and seedy and the yield is reduced. Owing to the fact that bush berries can survive a deficiency in water supply with less injury than can strawberries it is sometimes the custom of bush-berry growers in years of poor market returns to apply no more water than necessary to keep the plants alive and to make the best of diminished yields.

The irrigation season usually extends from late spring to some time in the fall, depending upon the beginning of winter rains, though after the fruiting season waterings are very infrequent. Plants in their first year require and are given less water than later, and the intervals between irrigations are more frequent during hot weather than in spring and fall.

In Pajaro Valley all bush berries are irrigated except in favored spots, such as those occupying sedimentary bottom-land soil adjacent to a hillside where a sufficient amount of moisture seeps down from the upper levels to replenish the supply below. Blackberries are irrigated once or twice before the blossoms drop, then every ten days to two weeks during the picking season, and once or twice thereafter, depending upon the lateness of fall rains. Sometimes they are irrigated as frequently as each week during the fruiting period, but the two-weeks interval more nearly represents the general practice. The time and length of the picking season of course depend upon the variety. In southern California the practice is generally the same during the picking season, and irrigation continues less frequently than before up to the time rains start and begins again with the cessation of rains in the spring. In some situations, such as on heavy soils near Moneta, irrigation takes place only once a month throughout the dry season, and on lighter soils it may take place twice each week while picking and every two or three weeks before and after. In Placer County blackberries are irrigated once or twice a week during the

fruiting season and several times while the plants are not in bearing.

In most sections of California dewberries are given practically the same irrigation treatment as blackberries, although in some sections in the southern part of the state, particularly on light soils, they are irrigated more frequently than blackberries under the same conditions. Being more shallow-rooting than many blackberry varieties they are more dependent upon irrigation.

Loganberries are in most sections given about the same amount of water as are dewberries. In Pajaro Valley, where many are grown, they are watered every two weeks from the end of the winter rains until the close of the fruiting season, and once or twice after that.

Fig. 17.—Young loganberries, recently irrigated with single furrows. The plants are set out on the general level of the field and the furrows are made later.

Sometimes they are irrigated more frequently while bearing fruit. The practice is similar in southern California, with often a greater seasonal application of water. Some growers irrigate alternate rows each week and pick from the unirrigated rows. Others in light soils irrigate every three or four days during the fruiting period.

Raspberries, as a rule, feel the effect of drought more quickly than blackberries. In southern California, where many are grown, the general practice is to irrigate every week during the fruiting season and every two to three weeks during the non-fruiting season in dry weather. In Santa Clara Valley the practice is about the same. In Placer County the practice is similar to that governing blackberries,

viz., to irrigate every three to seven days during the fruiting season and several times thereafter.

As before stated, gooseberries are found in only a few localities in California. Those grown in San Joaquin County are irrigated every ten days in the spring and until the crop has been removed, then about every two weeks through the summer and less frequently in the fall.

Adequate drainage is fully as essential for bush-berry fields as for strawberries, but the danger of waterlogging the soil is generally not so imminent owing to the lesser quantities of water applied.

MOISTURE CONSERVATION

The problem of conserving irrigation water in the soil is deserving of more attention from small-fruit growers than it often receives, for it involves not only economy in the application of water, but the maintenance of proper soil conditions as well.[4] The objections growers make to summer cultivation of strawberries are that the dragging of a harrow along the furrow tends to raise more or less dust, which impairs their marketability if it settles on the low-lying berries in any quantity; and, furthermore, that berries that may hang over the side of the ridge are bruised by the cultivator. For these reasons the harrow is kept out of the field as much as possible while fruit is being picked. A good mulch is usually kept on the tops of the ridges, but their area is less than one-half of the total, and is the only ground to which water is not directly applied. It is the wetted sides and bottoms of the furrows that are most in need of frequent cultivation.

The effect on the soil of failing to cultivate furrows in a strawberry field is shown in figure 12, page 17. The shrinking of the soil on drying produced large cracks through which moisture was lost, a condition which would have been prevented by harrowing or hand hoeing after irrigation. In this instance the soil was a fairly heavy clay loam, and the baking would not have been so pronounced in a lighter soil. From the standpoint of water application alone, frequent cultivations during the growing season are of considerable economic importance in that they decrease the amount of water required and consequently the cost of water, a factor which looms large in many sections of the state. The cost of cultivating is partially offset by the lessened cost of applying water. On the whole it would appear to be questionable whether, under ordinary circumstances, those growers

[4] Dr. C. B. Lipman attributes the apparent decrease in productive capacity of Pajaro Valley strawberry soils to the fact that water is applied too frequently and proper cultivation neglected. See Cal. Agr. Exp. Sta. Cir. 122.

who entirely dispense with summer cultivation can balance their gains against this higher water cost and lessened soil productivity caused by excessive applications of water.

Summer cultivation of strawberry fields is most generally found in southern California, where in some sections the furrows are harrowed after every irrigation, for it is recognized that moisture may be more effectively retained in the soil by so doing. In order to avoid bruising the berries the harrowings are often timed to take place immediately after ripe berries have been picked, as the damage to immature fruit is not so great. This practice is not universal in the south, however, for many growers there cultivate only in the spring. In some sections of the state where water is plentiful, the furrows are cultivated thoroughly before and after the fruiting season and between crops if possible, and frequent waterings are depended on to keep the soil loose during the picking season. This is the general practice in Pajaro Valley. Where this practice is followed the tops of the beds are hoed frequently to prevent weed growth and to maintain a surface mulch 1 or 2 inches deep. Care is taken in hoeing to keep away from the plants, for the roots are close to the surface and readily injured. Some growers cultivate thoroughly twice during the year, once in the spring and again in midsummer, and use the hoe as occasion requires to destroy weeds. Sometimes winter cultivation is practiced, especially in the south, where in parts of Los Angeles County strawberry fields are cultivated after every rain in the winter. Again there may be only one or two winter cultivations, and often they are confined to the late winter when the heaviest rains are over.

The type of cultivator used in many berry fields is an ordinary adjustable V-shaped spike-tooth one-horse harrow containing fourteen teeth. Some Pajaro Valley growers have a removable wooden drag, about 2 inches by 12 inches, which may be attached to the end of the cultivator to smooth the bottom of the furrow and spread the soil to the sides against the ridges, whence it has a tendency to wash down. Where the furrows are quite narrow, as in the single-row system, there is sometimes not enough space between the rows to permit the use of a horse-drawn cultivator and in such case it is necessary to do all stirring of the soil with a hoe or a hand cultivator. Sometimes the practice is to renew the furrows with a shovel-cultivator, or with an ordinary V-shaped cultivator with a broad shovel attached to the rear. In the Sebastopol district unirrigated strawberry fields are usually cultivated frequently throughout the season with a five-tooth V-shaped cultivator with tin shields along the sides to prevent the dirt from being thrown on the plants, for there they are not on raised beds.

Hand cultivators are sometimes used also. Generally horse-drawn harrows are preferred in berry fields because of the deeper cultivation and greater amount of work possible in a given time.

In the case of bush fruits different cultural methods are followed, for the spreading foliage often serves to shade the furrows and reduce surface evaporation and consequent loss of moisture, at the same time making harrowing close to the ridges more difficult. Furthermore, owing to the wide spaces between the rows, it is possible to plow during the non-growing season, an impossible operation in the case of the closely planted strawberry beds. One of the objections to cultivation during the fruiting period cited with reference to strawberries, viz., the danger of bruising the berries, is made by many growers of cane fruits; but where the canes are trained to fairly high trellises and are kept from spreading too far it is found practicable to run a harrow through the furrows after irrigating, and in many sections this is done. Deep cultivation during the growing season, however, is avoided for fear of injuring the fine roots that closely approach the surface of the ground.

In Pajaro Valley some growers plow twice during the winter, once toward the vines and again away from them, forming the furrows, and harrow after each plowing, with no cultivation thereafter. Sometimes both plowings come in the spring. Some growers plow three times in winter and spring, and harrow afterwards. Others are found to cultivate after each irrigation, or to double the number of irrigations and to cultivate after every second one. In southern California the general practice is to cultivate all bush berries after each irrigation and several times in winter, though some growers dispense with summer cultivation, others cultivate after every second irrigation, and still others twice between irrigations. In Alameda County, currants, which are not irrigated, are usually plowed twice in the spring, and then harrowed every few weeks until picking time, with some hand work for eradication of weeds. Bush fruits in Sonoma County are often plowed three times in the late winter and early spring, then cultivated with a spike-tooth harrow or shovel-cultivator from four to eight times, usually only once after picking has started. Blackberries of the upright type, such as Lawtons, are tied to single posts and cultivated both ways, but the trailing Himalayas, Mammoths, and loganberries are necessarily cultivated in one direction only. For where not irrigated, as in the two counties last named, bush fruits are even more dependent than elsewhere upon proper cultivation for the retention in the soil of the preceding winter's rainfall and its availability for the maturing of the fruit.

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